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Abundance of Marine Mammals in waters of the U.S. Southeastern Atlantic During Summer 2016

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1. BACKGROUND AND STUDY OBJECTIVES

In this report, we describe the results of a large vessel, visual line-transect survey conducted by the NMFS, Southeast Fisheries Science Center in U.S. waters of the U.S. Atlantic coast during the summer of 2016. The primary objective of the survey was to collect data and samples to support assessment of the abundance, habitats, and spatial distribution of cetaceans within U.S. waters. These data and resulting abundance estimates support the assessment of marine mammal stocks as required under the Marine Mammal Protection Act (MMPA) The MMPA requires that stocks of marine mammal species in U.S. waters be maintained at or above their optimum sustainable population level (OSP), defined as the number of animals which results in the maximum net productivity. To meet this requirement, the National Marine Fisheries Service (NMFS) conducts research to define stock structure, and for each stock, estimates annual human-caused mortality and potential biological removal (PBR), the maximum number of animals that may be removed from a stock due to human activities (*e.g.*, fisheries bycatch) while allowing the stock to reach or maintain its OSP. PBR is calculated following specific criteria using the estimated minimum abundance of the stock, its maximum net productivity rate (theoretical or estimated), and a recovery factor (Barlow et al., 1995; Wade and Angliss, 1997). The NMFS is required to prepare an annual Stock Assessment Report (SAR) for each stock to update abundance, stock structure, maximum net productivity, human-caused mortality, PBR, and status (*e.g.*, Hayes et al., 2019). This study describes the results of a summer 2016 vessel based survey and resulting abundance estimates for U.S. Western North Atlantic oceanic stocks of marine mammals.

2. METHODS

2.1 Survey Methods

The survey was conducted aboard the NOAA Ship *Gordon Gunter*, a 68-m (length) oceanographic research vessel, in waters off the southeast Atlantic coast of the U.S. The survey was conducted along "zig-zag" tracklines between central Florida and the Maryland/Delaware border and included shelf-break and inner continental slope waters within the U.S. EEZ (Figure 1). Survey effort was stratified into four geographic strata reflecting regional differences in hydrographic and bathymetric structure and spatial variation in the density and occurrence of different cetacean species.

Visual cetacean surveys were conducted from 30 June – 19 August, 2016. Standard ship-based, line-transect survey methods for cetaceans, similar to those used in the Pacific Ocean, Atlantic Ocean, and Gulf of Mexico, were used (*e.g.*, Barlow, 1995; Mullin and Fulling, 2003). The survey employed the "independent observer" methodology to improve estimates of sighting probability. This approach was similar to that used during the summer of 2004 (Garrison et al., 2011). The observer teams were stationed on the flying bridge (height above water = 13.9 m) and the bridge wings (height above water = 11.2 m). The two teams were isolated from one another to avoid "cueing" each other to the presence of marine mammals. Both teams consisted of four observers rotating through two positions at 30 min. intervals. A recorder position stationed on the bridge maintained communication with both teams and recorded data on sightings by each team using a computerized data entry program interfaced with a global positioning system (GPS) receiver. For each team, at least one observer experienced in ship-based, line-transect methods and identification of cetaceans was present on the flying bridge or bridge wings at all times. The left and right side observers searched to the horizon in the arc from 10° right and left of the ship's bow to the left and right beams (90°), respectively, using 25x "bigeye" binoculars. Survey speed was usually 18 km hr^{-1} (~10 kt) but varied with sea conditions. The effectiveness of visual line transect survey effort is severely limited during high sea state and poor visibility conditions (e.g., fog, haze, rain). Survey effort was therefore suspended during heavy seas (Beaufort sea state > 5) and rain.

For each cetacean sighting, time, position, bearing and reticle (a measure of radial distance) of the sighting, species, group-size, behavior, bottom depth, sea surface temperature, and associated animals (e.g., seabirds, fish) were recorded. The bearing and radial distance for groups sighted without 25x binoculars and close to the ship were estimated. Survey effort data were automatically recorded every 30 sec and included the ship's position and heading, effort status, observer positions, and environmental conditions which could affect the observers' ability to sight animals (e.g., Beaufort sea state, trackline glare, etc.). Cetaceans were identified to the lowest taxonomic level possible.

2.2 Analytical Methods

Abundance estimates were derived using the independent observer approach assuming point independence (Laake and Borchers, 2004) implemented in package mrds (version 2.21, Laake et al., 2020) in the R statistical programming language. Briefly, this approach is an extension of standard line-transect distance analysis that includes direct estimation of sighting probability on the trackline. The probability of sighting a particular group is the product of two probability components. The first probability corresponds to the "standard" sighting function such that the probability of detection declines with increasing distance from the trackline following a known functional form (typically the half-normal or hazard function). The second component is the likelihood of detection on the trackline which is modeled using a logistic regression approach and the "capture histories" of each sighting (i.e. seen by one or both teams). The logistic model can include factors that may affect the probability of detection such as viewing or weather conditions. Details on the derivation, assumptions, and implementation of the estimation approach are provided in Laake and Borchers (2004).

Sighting probability was estimated separately for four groups of cetaceans: dolphins, small whales, large whales, and cryptic species to account for differences in body size and surface behavior and associated differences in sighting probability (Table 1; Barlow, 1995; Mullin and Fulling, 2003; Garrison et al., 2011). "Cryptic" species including beaked whales and pygmy/dwarf sperm whales (*Kogia spp.*) were grouped because these taxa are deep divers that have only a limited availability to visual surveys due to the long time spent underwater and difficulty in seeing them when at the surface. For each species group, sighting probability was estimated globally across strata. The perpendicular sighting distances were right-truncated to remove roughly 10% of the sightings with the farthest distances (Buckland *et al.,* 2001). The form of the sighting function (hazard vs. half-normal) and the inclusion of covariates (including observer platform, group size, sea state, glare, swell height, wind speed, cloud cover, and survey conditions) in the mark-recapture and detection probability components of the models were evaluated using model selection based upon the Akaike Information Criterion (AIC, Laake and Borchers, 2004). Stratified abundance estimates for each individual taxon were calculated using stratum and species level encounter rates (groups per km of trackline) and mean group size.

3. RESULTS

A total of 5,168 km of survey effort were completed during the survey (Figure 1). Weather conditions were good to fair throughout much of the survey, with sea states of Beaufort 2-4 on most survey days, averaging 3.2 throughout the cruise.

Cetacean sightings by stratum are summarized in Table 1. The most common species encountered were bottlenose dolphins and pilot whales. While pilot whales (*Globicephala spp.*) were not identified explicitly to species during the survey, the spatial range of the survey, depth, and environmental conditions suggest that encountered pilot whales were likely exclusively short-finned pilot whales (*Globicephala macrorhynchus*, Garrison and Palka, 2018). Cetacean sightings were most frequent along the shelf break in the mid-Atlantic north of Cape Hatteras, NC (Figure 1). Sperm whales were observed in high densities along the mid-Atlantic shelf break and sporadically in deeper waters. Other large whale sightings included fin whales and one sighting of Minke whales (Figure 2). Pilot whales and Risso's dolphins were the primary small whales sighted during the survey with pilot whales primarily along the mid-Atlantic shelf break (Figure 3). A variety of delphinids were encountered during the survey dominated by Offshore Bottlenose dolphins and Atlantic spotted dolphins (Figure 4). Pygmy/Dwarf sperm whales and beaked whales were observed sporadically in deeper waters of the survey area, with notable high concentrations in the offshore southern Atlantic stratum (Figure 5).

Selected models for the detection functions for each taxonomic group are shown in Table 2. The selected models provided adequate fits to the data as indicated by non-significant (p-value > 0.05) GOF tests, which the exception of the small whale model where p = 0.005 (Table 3). However, the lack of fit in this model was primarily in the tail of the distribution where there were no duplicate sightings at large perpendicular sighting distances (Figure 7). This lack of fit likely had relatively little impact on the estimate of detection probability on the trackline. Detection probability functions for each species group are shown in Figures 6-9. Notably, there was no apparent effect of distance (or other factors) in the mark-recapture component of the dolphin model, and no evidence of a decline in resight rates with increasing distance from the trackline (Figure 8). The fit of the model for cryptic species is relatively poor (Figure 9); however, this is to be expected due to the small sample size.

Abundance estimates for each species are shown in Table 3. The abundance estimates for the deep-diving “cryptic” species are likely significantly negatively biased due to their long dive times and resulting low availability to visual observers. The uncertainty around all abundance estimates is relatively high, with the best CVs ranging between 0.29 – 0.47 for the more common species. Rare species with a smaller number of sightings had higher CVs that exceeded 0.9 (Table 3). The majority of this variability was associated with variation in encounter rates among different tracklines rather than variation in group sizes or uncertainty in the detection function. Therefore, spatially explicit estimation methods or alternative stratification may be able to reduce the uncertainty in resulting abundance estimates. The abundance estimates presented in Table 3 will be included in the annual stock assessment reports mandated by the MMPA.

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TABLES

Table 1. Number of cetacean groups and individuals observed during GU1605. Counts include both on effort and off effort sightings.

Species	Species Group	Number of Groups	Number of Individuals
Atlantic spotted dolphin	Dolphins	31	971
Blainville's beaked whale	Cryptic	1	3
Bottlenose dolphin	Dolphins	90	1170
Bottlenose/Spotted dolphin	Dolphins	4	30
Clymene dolphin	Dolphins	2	122
Common dolphin	Dolphins	4	307
Cuvier's beaked whale	Cryptic	21	48
False killer whale	Sm. Whales	1	9
Fin whale	Lg. Whales	3	6
Gervais' beaked whale	Cryptic	1	1
Killer whale	Sm. Whales	1	5
Melon-headed/Pygmy killer whale	Sm. Whales	2	10
Minke whale	Lg. Whales	1	1
Pantropical spotted dolphin	Dolphins	7	265
Pilot whales	Sm. Whales	64	944
Pygmy/Dwarf sperm whale	Cryptic	36	62
Risso's dolphin	Sm. Whales	15	139
Sperm whale	Lg. Whales	37	70
Spinner dolphin	Dolphins	1	170
Stenella sp.	Dolphins	7	170
Striped dolphin	Dolphins	6	759
Unid. Baleen Whale	Lg. Whales	1	1
Unid. dolphin	Dolphins	82	1863
Unid. large whale	Lg. Whales	5	5
Unid. Mesoplondont	Cryptic	22	48
Unid. odontocete	Sm. Whales	25	35
Unid. small whale	Sm. Whales	19	36
Unid. Ziphiid	Cryptic	40	77

Table 2. Detection probability model parameters and estimated detection probabilities for each taxa group. HN = Half-normal function, HR = Hazard rate model function. DS = distance function model component. MR = Mark-recapture model component. DS and MR Model columns indicates the covariates included in the selected model. p0 indicates estimated detection probability on the trackline while p indicates overall detection probability in the surveyed strip. p Chi-Sq GOF indicates the p-value for a chi-square goodness of fit test between the observed data and the outcomes of the MRDS model. CV = coefficient of variation.

Group	DS Model	MR Model	p Chi-sq GOF	p0 (CV)	p (CV)
Lg. Whale	HN: ss	dist x obs	0.257	0.930 (0.070)	0.617 (0.194)
Sm. Whale	HR: conditions	dist x obs, ss	0.005	0.700 (0.192)	0.216 (0.252)
Dolphins	HR: glare, conditions, log (group size)	null	0.109	0.760 (0.049)	0.178 (0.237)
Cryptic	HN: vis, cloud cover	dist	0.056	0.719 (0.159)	0.349 (0.186)

Table 3. Abundance estimates for cetacean species during GU1605. CV = coefficient of variation.

Group	Species	Density (n km^{-2})	Abundance	CV
Cryptic	Cuvier's beaked whale	0.0044	1847.4	0.486
Cryptic	Gervais' beaked whale	0.0002	67.5	0.982
Cryptic	Blainville's beaked whale*	0.0000	0	-
Cryptic	Pygmy/Dwarf sperm whale	0.0077	3202.6	0.586
Cryptic	Unid. Mesoplondont	0.0053	2212.2	0.428
Cryptic	Unid. Ziphiid	0.0080	3347.1	0.286
Dolphin	Atlantic spotted dolphin	0.0760	31674.1	0.327
Dolphin	Bottlenose dolphin	0.1078	44893.0	0.286
Dolphin	Bottlenose/Spotted dolphin	0.0047	1967.5	0.724
Dolphin	Clymene dolphin	0.0102	4237.8	1.030
Dolphin	Common dolphin	0.0022	899.9	0.566
Dolphin	Pantropical spotted dolphin	0.0158	6592.8	0.515
Dolphin	Spinner dolphin	0.0095	3942.5	1.029
Dolphin	Stenella sp.	0.0146	6066.3	0.666
Dolphin	Striped dolphin	0.0580	24163.4	0.657
Dolphin	Unid. dolphin	0.0789	32877.7	0.318
Lg. Whale	Fin whale**	0.0000	0.0	-
Lg. Whale	Minke whale	<0.0001	16.8	0.983
Lg. Whale	Sperm whale	0.0025	1028.2	0.349
Lg. Whale	Unid. Baleen Whale	<0.0001	5.5	0.997
Lg. Whale	unid. large whale	<0.0001	59.9	0.584
Sm. Whale	False killer whale	0.0015	609.5	1.078
Sm. Whale	Killer whale	0.0009	365.1	0.951
Sm. Whale	Melon-headed/Pygmy killer whale	0.0011	463.7	0.776
Sm. Whale	Short-finned Pilot whales	0.0656	25114.5	0.273
Sm. Whale	Risso's dolphin	0.0174	7245.0	0.440
Sm. Whale	Unid. odontocete	0.0046	1903.7	0.394
Sm. Whale	Unid. small whale	0.0043	1774.5	0.328

*One Blainville's beaked whale sighting was observed off effort; **3 fin whale sightings were observed with one sighting on effort; however, it was observed beyond the right truncation distance for the distance function. Therefore, the abundance estimate is 0.

FIGURES

Figure 1. Survey tracklines and cetacean sightings during GU1605. Stratum boundaries are indicated with the inner boundary defined by the 200m isobath and the outer boundary defined by the US EEZ. On effort tracklines are indicated along with the locations of marine mammal groups sightings.

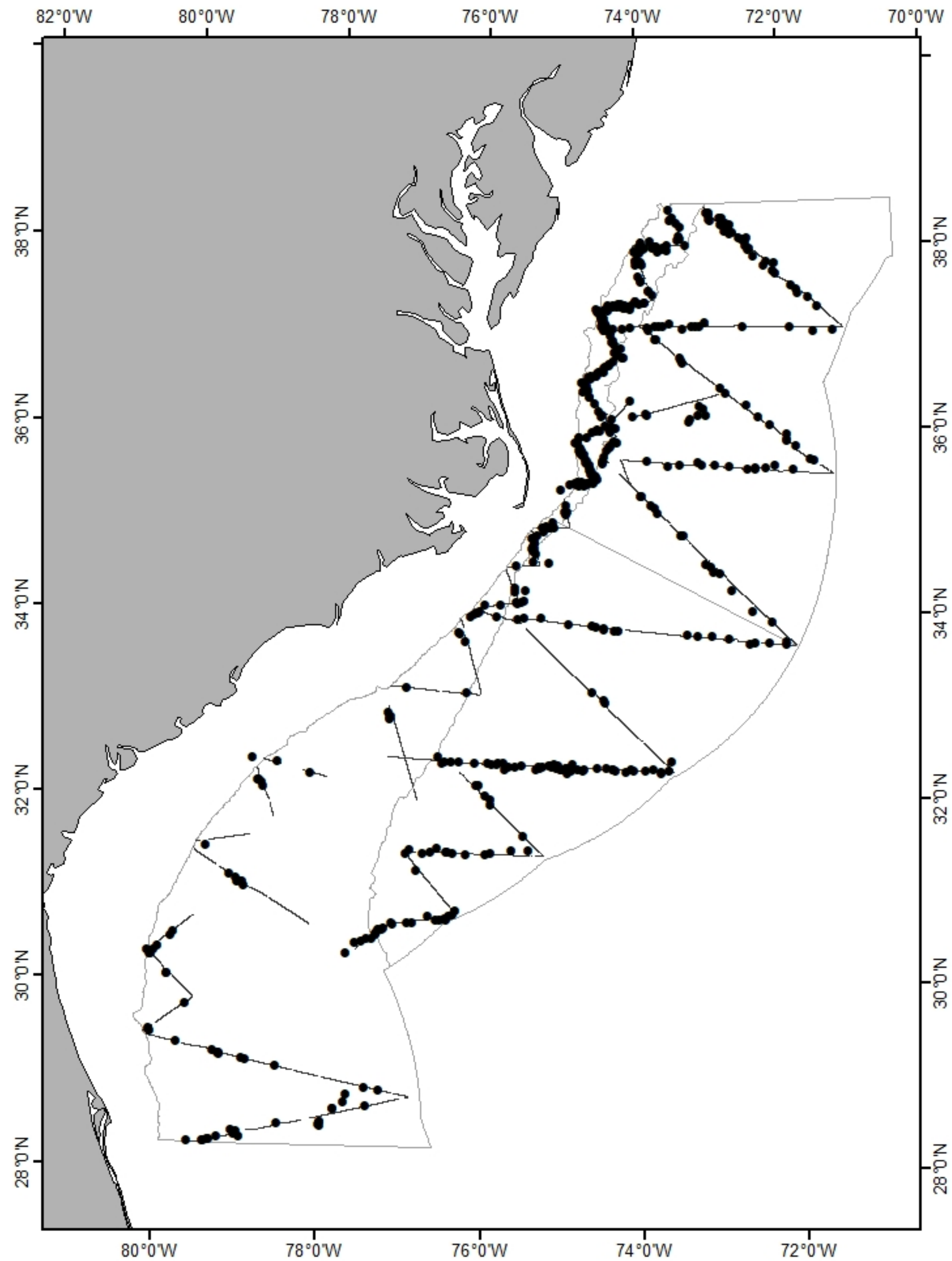

Figure 2. Large whale sightings during GU1605

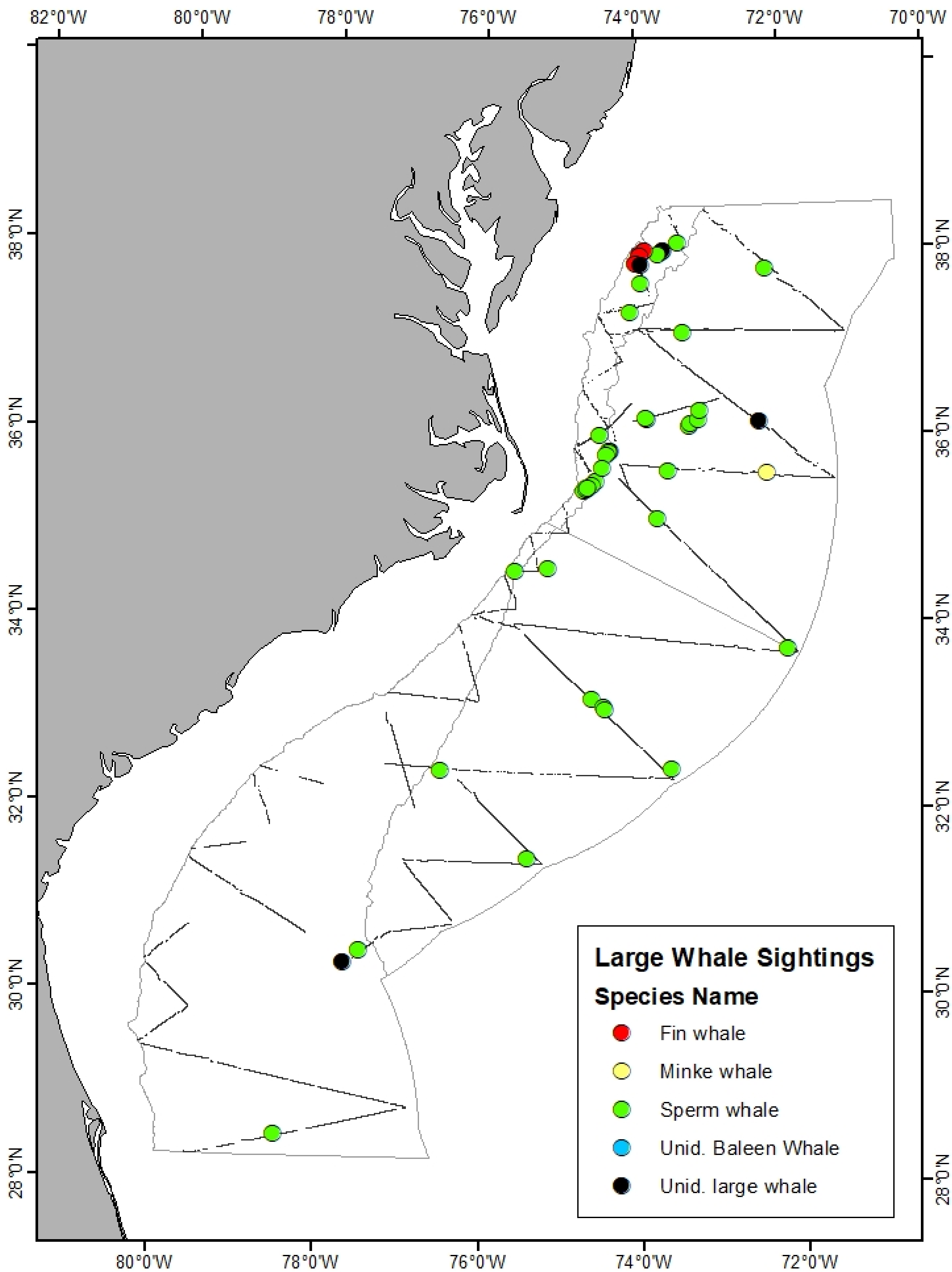

Figure 3. Small whale sightings during GU1605.

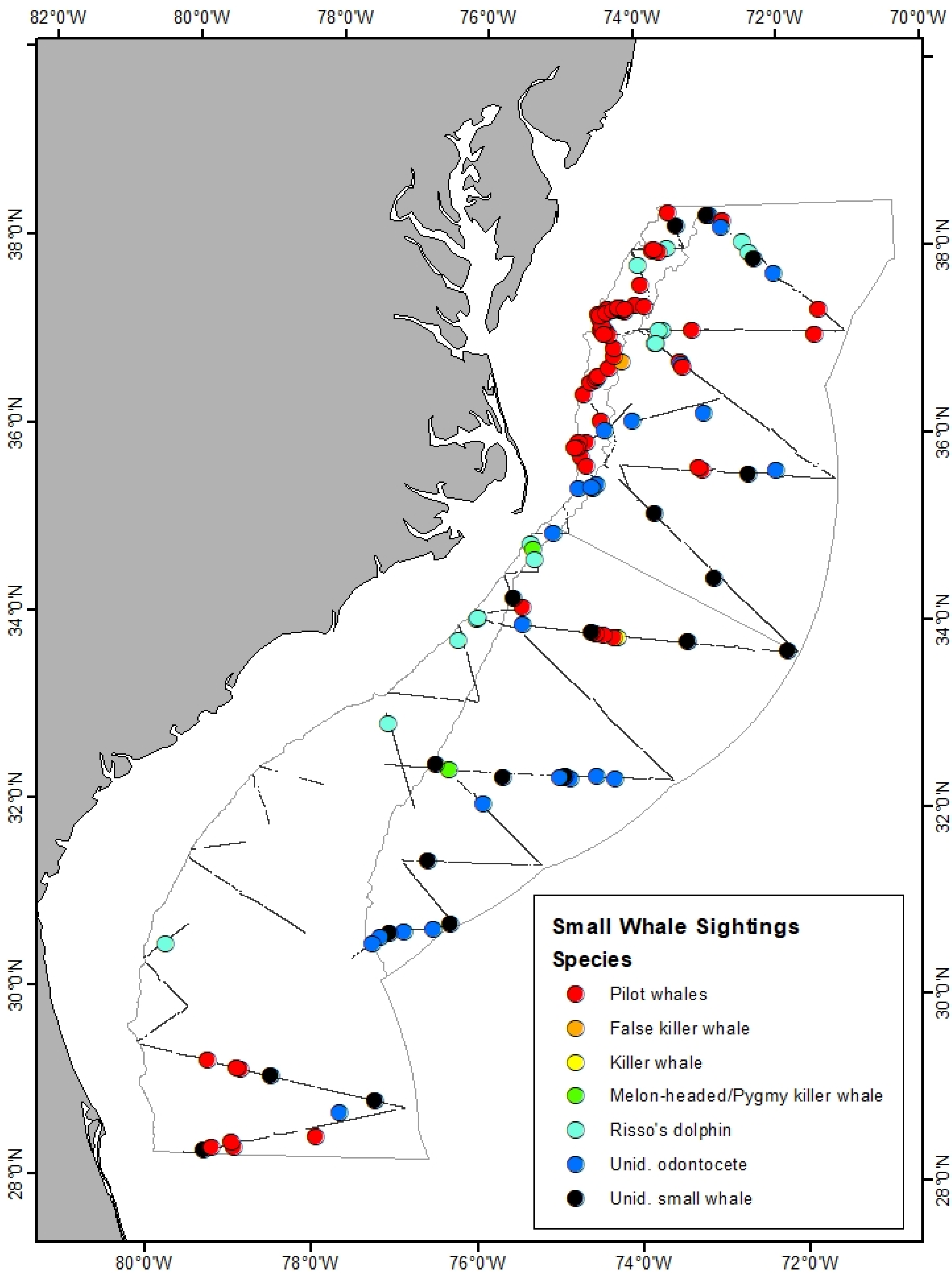

Figure 4. Dolphin sightings during GU1605.

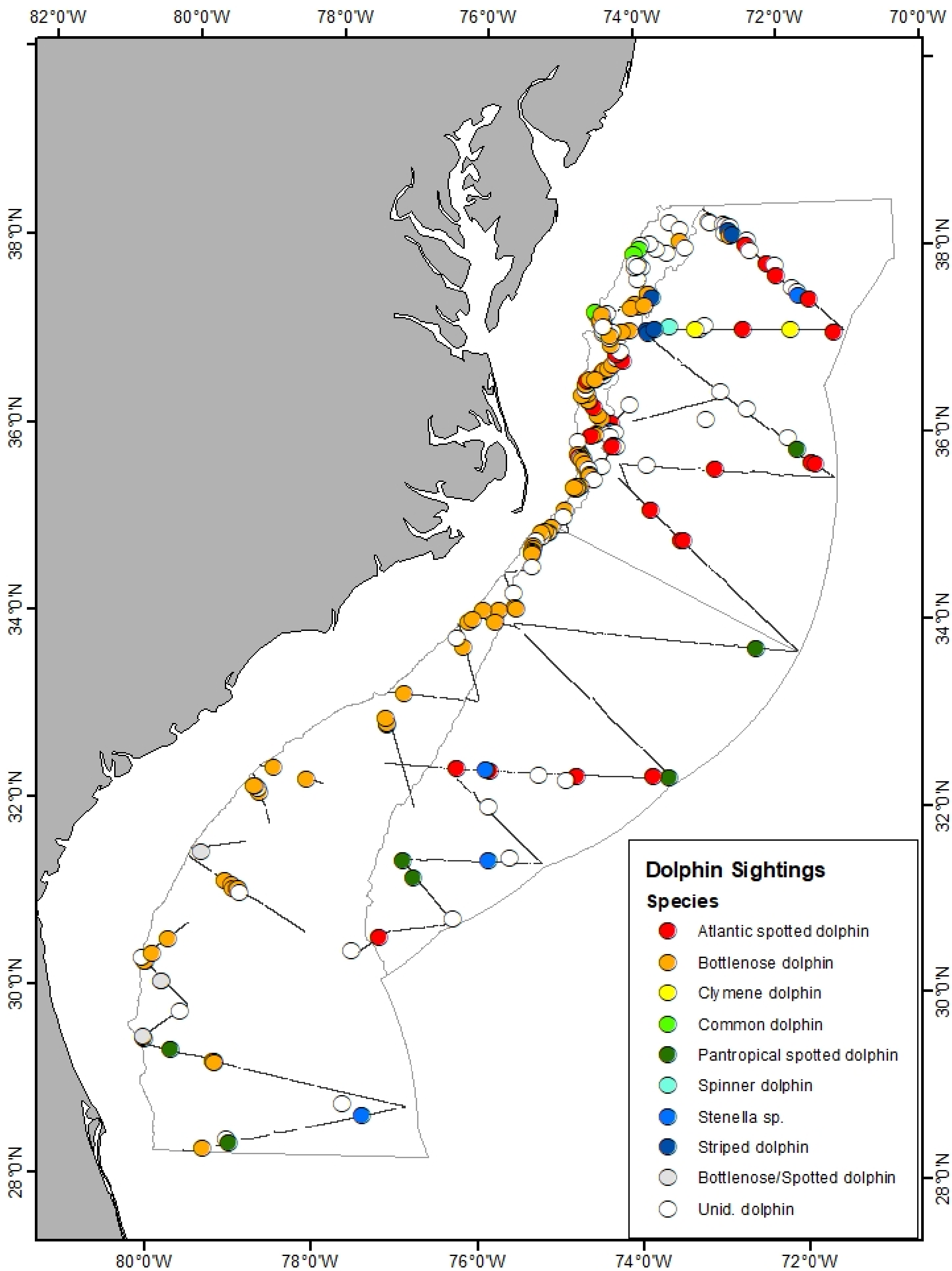

Figure 5. Cryptic species sightings during GU1605.

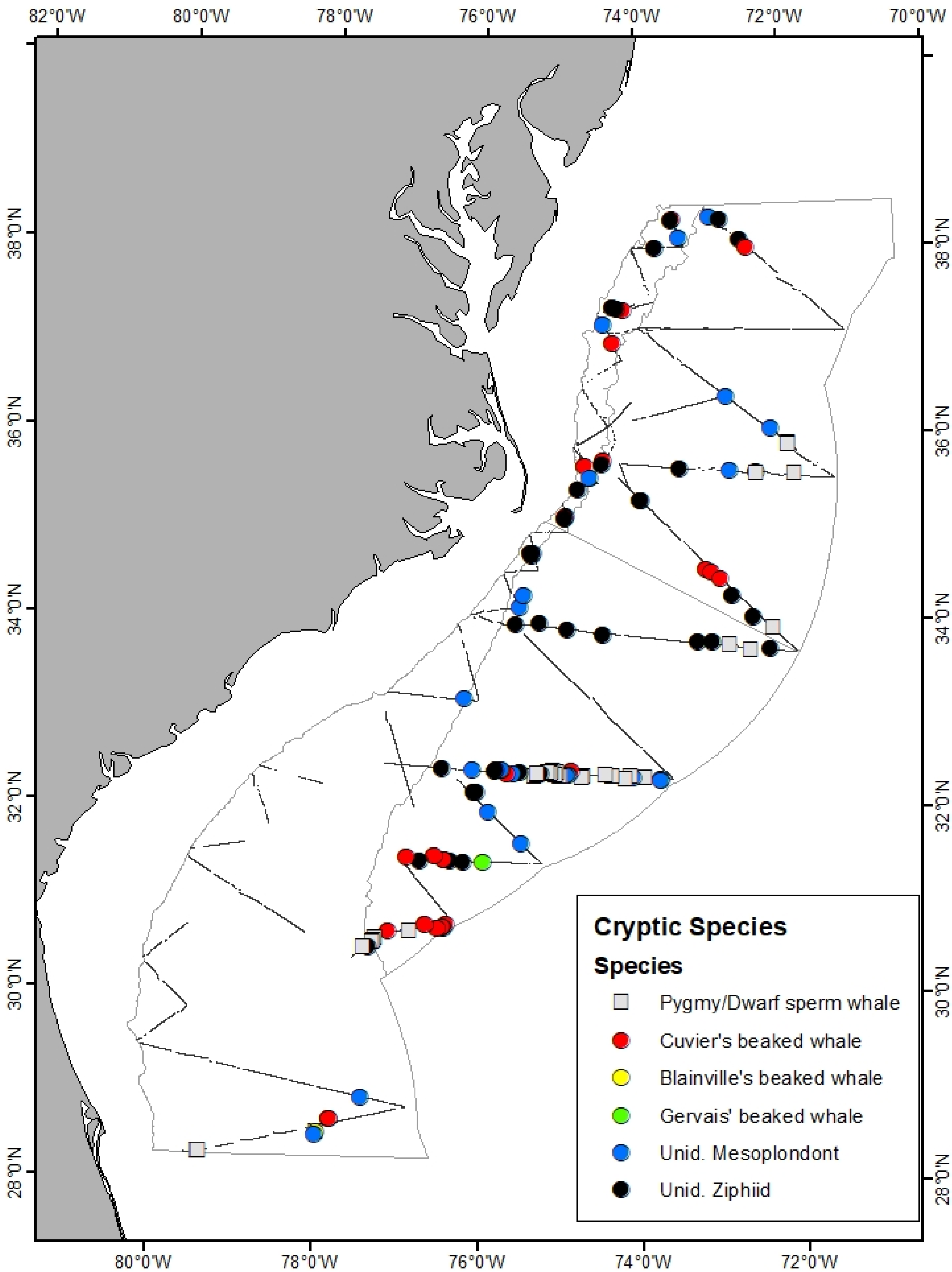

Figure 6. Detection probability functions for large whales.

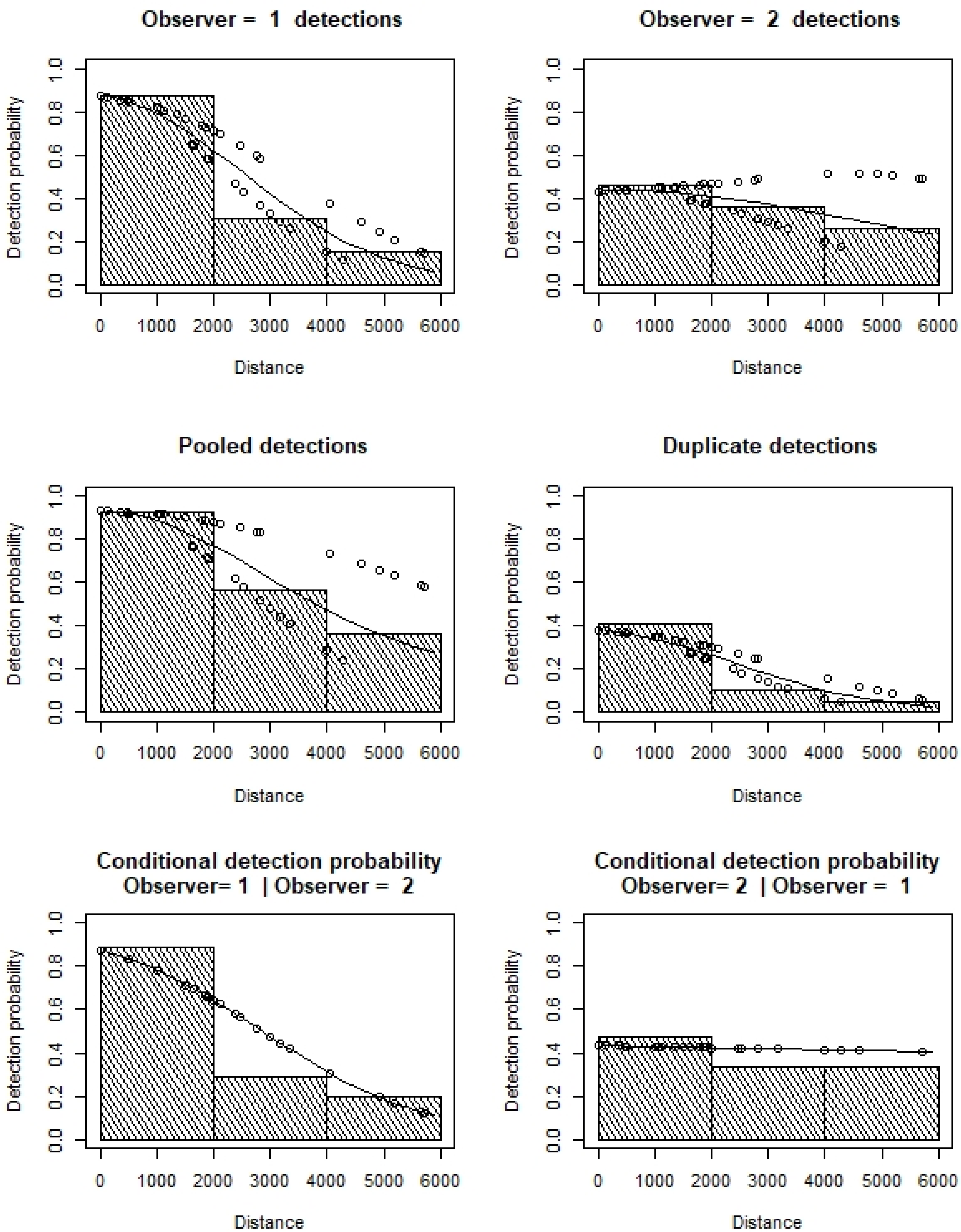

Figure 7. Detection function for small whales.

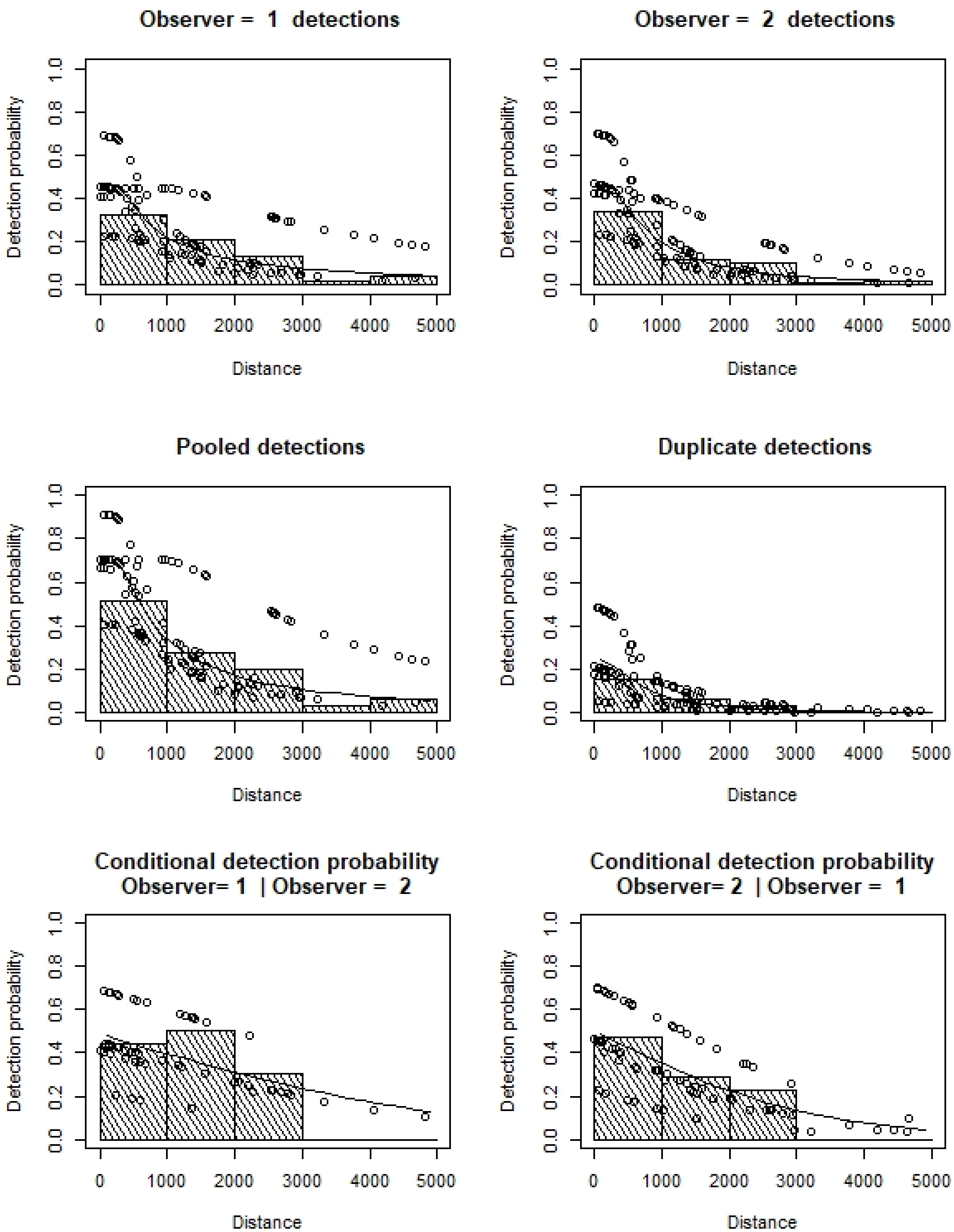

Figure 8. Detection functions for dolphins.

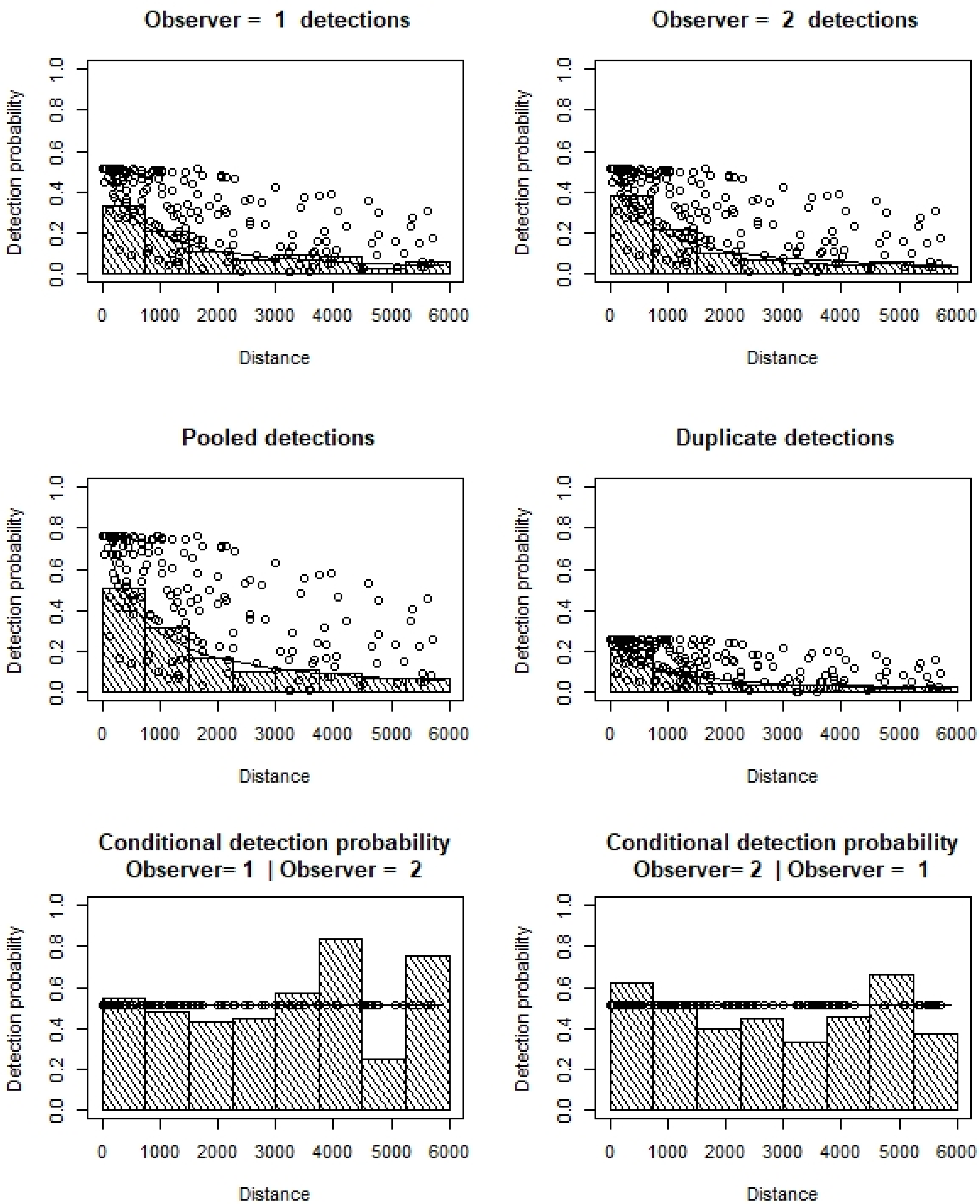

Figure 9. Detection functions for cryptic species.